VACANCIES IN THE GRADE OF ASSISTANT CIVIL ENGINEER, U. S. NAVY

APPICATIONS are being received at the Bureau of Yards and Docks, Navy Department, Washington, D. C., to fill 30 vacancies, more or less, in the commissioned grade of assistant civil engineer, U. S. Navy, with the rank of lieutenant (junior grade). The pay and allowances at entrance are approximately $3,200 per annum, with increases up to $9,000, depending upon length of service and promotions.

The candidate must be an American citizen, between the ages of 21 and 34 years on August 1, 1920; must have received a degree in engineering from a college or university of recognized standing; must have had not less than 12 months' practical professional experience since graduation, and must be of good moral character and repute.

The preliminary examination to determine general fitness will be based on papers submitted by the candidates, reaching the Board on or before August 23, 1920, covering college record, testimonials, references and professional experience. The candidate is not required to report in person for the preliminary examination. Physical examination by a board of medical examiners will be made of those candidates who qualify in the preliminary examination.

Those who qualify in the preliminary and physical examinations will take the final oral and written examinations to be held in Washington, D. C., as soon as possible after the preliminary examination papers have been passed on by the Board.

Officers of the Corps of Civil Engineers are detailed principally to the various navy yards and naval stations to supervise the work under the Bureau of Yards and Docks, Navy Department, Washington, D. C., consisting of the design and construction of all the public works of the naval establishment on shore as well as the maintenance and repair of existing structures. The work is exceptionally varied and offers an attractive field for able and ambitious young engineers.

C. W. PARKS,
Chief of Bureau

ARISTOTLE AND GALILEO ON FALLING BODIES

A DRAMATIC event in the history of physics is Galileo's dropping a one pound shot and a hundred pound shot together from the leaning tower of Pisa, to disprove Aristotle's law of falling bodies. In 1913 Professor H. H. Turner of Oxford, in a lecture at the Royal Institution, quoted Galileo's version of Aristotle's law:

> Aristotle said that a weight of ten pounds, for example, fell ten times as fast as a weight of one pound.[1]

To this J. H. Hardcastle replied,[2] "Aristotle never said this at all"; he refers any one who "wishes to find out for himself" to Aristotle's "Physica," Book IV., cap. 8. He does not quote from Aristotle, but quotes from Thomas Aquinas's commentary on the passage in Aristotle to which this reference points. Accepting Hardcastle's statement, G. Greenhill, William Ramsay and Oliver Lodge arrive at the conclusion[3] that Aristotle has been misunderstood. Greenhill interprets Aristotle as teaching "that the terminal velocity of a body in a medium is proportional to the weight," a law "justified by Newton in his experiments in St. Paul's"[4] and exemplified in the motion of "a raindrop or hailstone falling vertically in the air, or of a smoke particle up the chimney"; Galileo discussed an altogether different question, viz., "the start of such a body from rest." Ramsay refers to Ostwald as pointing out that "Aristotle was much more impressed with the retarding effect on the velocity of the mass of the medium through which the falling mass fell, than with the laws of 'free fall.'" Lodge emphasizes "the fact that 'terminal velocity' is the best instance of Newton's first law of motion in actual operation."

[1] Galileo, "Dialogues concerning two New Sciences" (Ed. Crew and De Salvio), New York, 1914, p. 62.

[2] *Nature* [London], Vol. 92, 1914, p. 584.

[3] *Nature*, Vol. 92, pp. 584, 585, 606.

[4] "Principia," Book II., Prop. 40.

These remarks are interesting, but not altogether to the point. Those modern apologists do not actually quote Aristotle, nor do they base their reasoning on what Aristotle actually said.

Aristotle discusses falling bodies in six or more different parts of his "Physica" and "De Cœlo."

1. He considers[5] a body falling through media of different densities—air, water and media indefinitely rare. Then he considers also bodies of different weights falling through the same medium. Endeavoring to disprove the existence of a vacuum, Aristotle says:

> That which is heavier . . ., other things being equal, moves faster through the same space, and indeed faster according to the ratio of the magnitudes of the things, so that this must happen also through a vacuum. But this is impossible; for why should it move faster? In a plenum this is necessarily true, because the larger moves more rapidly by its power of greater penetration.

Thus, according to this Aristotelian passage, not only do the larger bodies move faster through a medium, but they would move faster even through a vacuum, if such existed.

2. Aristotle asserts[6] that each of the bodies constituting the universe was originally at rest (as taught by Anaxagoras), that each was heavy or light and had power to move.

> For suppose *A* without weight, but *B* possessing weight; and let *A* pass over a space *CD*, but *B* in the same time passes over a space *CE*—for that which has weight will be carried through the larger space. If now the heavy body be divided in the proportion that space *CE* bears to *CD*, . . . and if the whole is carried through the whole space *CE*, then it must be that a part in the same time would be carried through *CD*. Consequently the body without weight and the one possessing weight pass over the same distance, which is impossible.

Here Aristotle's law is applied to bodies initially at rest.

3. Aristotle argues[7] that "if there were an unlimited increase in the weight, there would be also an unlimited increase in velocity." The volume of a falling body is specially considered in "De Cœlo," Book IV., cap. 1:[8]

4. In "De Cœlo," Book I., cap 6,[9] we find:

> If such and such a weight is moved so and so far in such and such a time, then some larger weight will be moved through the same distance in still shorter time, shorter in the inverse ratio of the weights. . . . A limited weight can pass over any limited line in a limited time.

5. In "De Cœlo," Book IV., cap. 2,[10] Aristotle argues, likewise, that the more fire will proportionally move upward with greater speed and the less fire with less speed, and similarly for the downward motion of more gold or more lead. Here, as in most other passages, the shapes of the moving bodies are not considered.

The above shows that Aristotle considered his law applicable when the motion took place from rest as in (2), when there was no upper limit to the weight that the moving body may have as in (3), when the time of motion may be reduced or increased as in (4), and when the moving bodies are different weights of any metal, like gold or lead, as in (5). No restriction is placed by Aristotle to the combination of some or all of these four conditions in one and the same motion. To our surprise, he was willing to apply his law even to motion in a vacuum (were a vacuum possible) as is seen in (1). It appears therefore that Aristotle allowed his law a generality of application which certainly did include the special conditions under which Galileo performed his experiment of dropping a one-pound shot and a hundred-pound shot through the air from the leaning tower.

Florian Cajori
University of California

[5] "Physica," Book IV., cap. 8. We are using Carl Prantl's "Aristoteles' Werke. Griechisch und Deutsch," Bd. I., Leipzig, 1854, pp. 187–191.

[6] "De Cœlo," Book III., cap. 2; Prantl, Vol. 2, pp. 203–205.

[7] "De Cœlo," Book I., cap. 8; Prantl, Vol. 2, p. 65.

> That body is heavier than another which, in an equal bulk, moves downward quicker.

[8] Prantl, Vol. 2, p. 243.

[9] Prantl, Vol. 2, p. 47.

[10] Prantl, Vol. 2, p. 249.